and not acuminate, nor so wide at the base as those of *B. fontana*. The fertile plants from Mr. M'Ivor are very different in appearance, being very much smaller; yet they appear to belong to the same species.

It seems impossible in the absence of authentic specimens to ascertain if this be the *B. fontana β. pumila*, "caule abbreviato simpliciusculo; foliis lanceolatis," of Turner, Musc. Hibern. p. 107. t. 10. f. 1. The only part of his description that points to *B. pumila* is "foliis intensius viridibus, nec acuminatis, nec cuspidatis," besides the observations that it is much more slender and shorter than *α*. The figure does not at all resemble the fertile *B. pumila* from Dollar, and that of the leaf represents it as described, "multo luculentius serratis;" from which it is just possible that the plant intended by Turner may be *B. rigida*, which has been gathered in Ireland.

156. *B. pomiformis*, Hedw.

On sandy banks: not very common.

Tribe VII. MNIACEÆ.

Genus 1. *Fissidens*, Hedw.

157. *F. taxifolius* (Linn.), Hedw.

Very common.

Stems of this species may sometimes be found with the seta arising from just below the top.

[To be continued.]

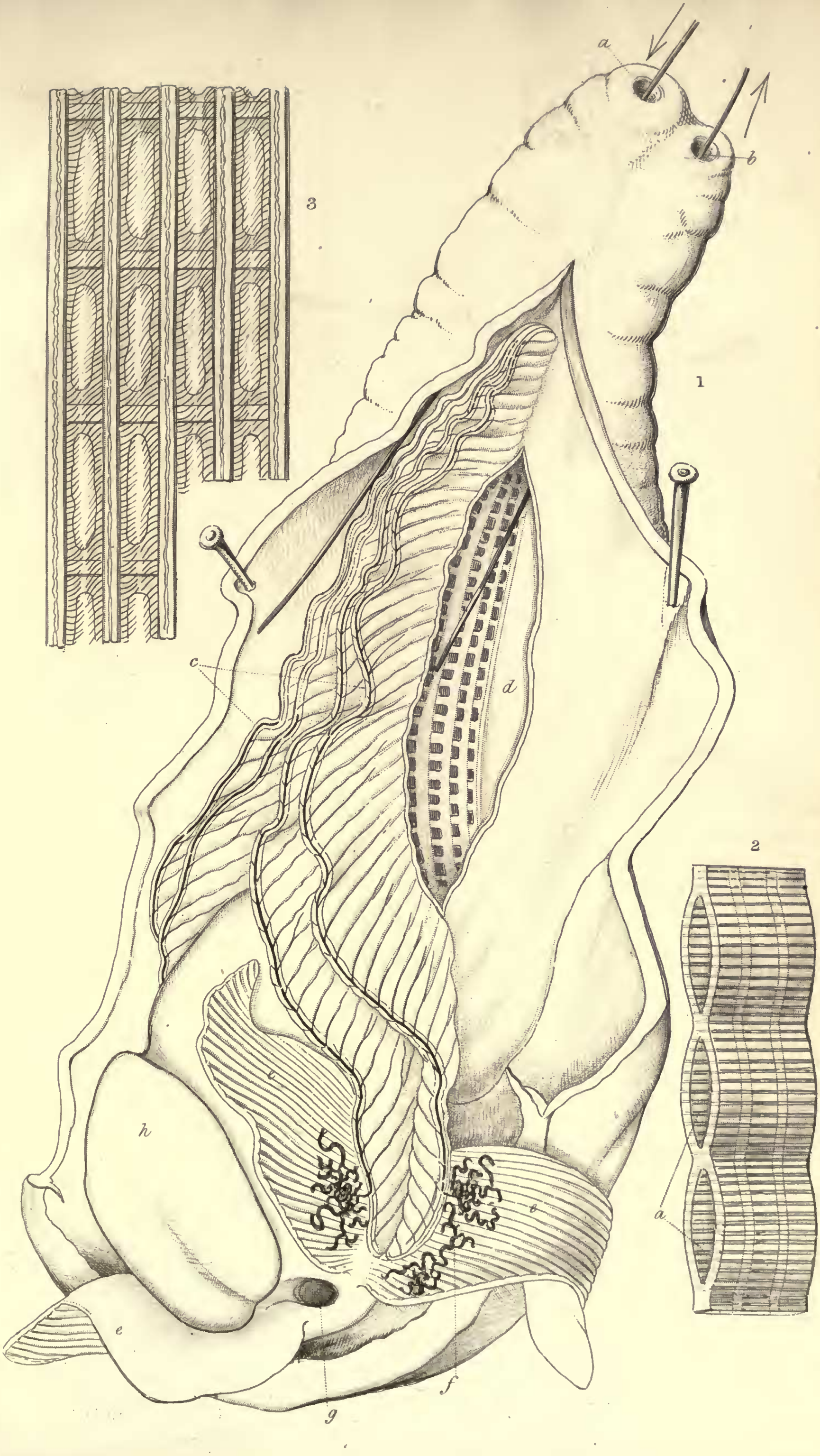
XXX.—*On the Branchial Currents in* Pholas *and* Mya.

By JOSHUA ALDER and ALBANY HANCOCK.

[With a Plate.]

THE existence of branchial currents in the Bivalve Mollusca, produced by the action of cilia, and admitted and discharged by different apertures, though denied by one or two authors, may be considered sufficiently established to allow of little further discussion. But though most naturalists admit the existence and action of these currents as a general law, yet exceptions have been claimed for some families and genera, whose anatomical structure is supposed to present an insuperable obstacle to the existence of inhalant and exhalant currents by different siphons; these siphons, as it is thought, having no communication internally. Among the families so placed are the *Myadæ* and *Pholadidæ*.

Mr. Garner in his excellent essay on the Anatomy of the *Lamellibranchiata*, published in the 'Transactions of the Zoolo-



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gical Society*,' and more in detail in Charlesworth's 'Magazine of Natural History †,' after describing the structure of those genera in which the water is acknowledged to flow in by the branchial siphon, and to be discharged by the anal one, goes on to say that "in the *Solen, Hiatella, Mya, Pholas, Teredo,* &c., a different disposition takes place. Here the branchiæ are prolonged into the inferior siphon, and as they are not separated from the base of the foot within, nor from the mantle without, the water drawn through the inferior orifice must make its exit by the same or by the anterior opening. But water is also drawn in by the other, and so gets access to the interior interlamellar spaces of the branchiæ; and by this superior siphon, ova, fæces, and secretions are discharged." From the statement here made it would appear that Mr. Garner draws his inferences from the anatomy of the animal alone, and not from actual observation of the currents, as he seems doubtful whether the water received by the branchial siphon is discharged by the same orifice or by the anterior opening.

Mr. Clark, however, has gone much further than Mr. Garner in an attempt to establish a somewhat similar view of the subject. By a series of experiments with mercurial injections, introduced principally through the anal siphon, he claims to have proved that no communication can exist between it and the branchial cavity; and by other experiments upon the living animal, that gentleman announces that he has made a most important discovery, namely:—that "nine-tenths, if not all, the water to bathe the branchiæ is admitted by the *pedal* gape, and ejected *only* by the branchial siphon; the anal one alone inhales water and discharges it;" and that "in the close-mantle *Solenidæ, Myadæ, Lutrariæ,* &c., as well as in the open-mantle *Veneres, Cardia,* &c., the water is only admitted into the branchial vault at the pedal or ventral aperture by the simple opening of the valves, and ejected, according to the structure of their respective sacs, either by the branchial issue alone, as in the *Pholades,* &c., or as in the *Veneres, Cardia,* &c., by the two confluent orifices, which are in fact but one branchial conduit."

This conclusion, so contrary to the experience of other naturalists, has been deduced from the following experiment. A *Pholas,* inflated with water, was lifted up and held in an inverted position with the siphons downwards, until all the water had run out. More water of course ran out of the branchial than the anal siphon, as might have been inferred from its larger aperture, the absence of a valve, and its more direct communication with the branchial cavity, in which the principal part of the water is contained. On replacing the animal in water, a powerful column was observed to pass in through the pedal opening, while none was seen to enter by the siphons, these latter being probably closed by the animal in consequence of the unnatural usage it had been subjected to; but whether this be the case or not, it was to be expected that, by a known law of hydrostatics, the greater flow of water would be through the larger aperture until the equilibrium was restored. This, however, is a special case having nothing to do with the regular branchial currents, as has been before pointed out to Mr. Clark; yet this experiment is considered to have finally disposed of the complicated scheme, as it is called, of other authors, by which name is designated the simple observed fact, that water for branchial purposes is received and expelled by the action of cilia and by separate orifices.

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* Vol. ii. p. 91.

† Vol. iii.

Let us for a moment consider what would be the consequence of Mr. Clark's supposition that these animals obtain water only by the pedal gape. Nearly all of them pass their lives buried in sand or mud, or immured in solid stone, with only a small aperture externally, the pedal opening being beneath, and the siphonal tubes in communication with the open sea. Yet Mr. Clark would have these animals receive only the small quantity of water charged with sand and mud that finds its way to the bottom of the cavity, rather than draw their supply from the pure element on the surface, by means of their long siphons, which, it is generally supposed, nature has furnished them with for this very purpose.

It has long been known to us from actual observation that the *Pholades* and *Myadæ* do draw in a current of water by the branchial siphon, and that it is expelled by the anal one, as is the case with the other bivalves. To convince himself of this fact, it is only necessary for an observer to place a Pholas in a glass of sea-water and allow it to remain undisturbed for some time, in order that the animal may stretch out its tubes and recover its natural quiescent state. Then by gently adding a little fresh sea-water slightly charged with floating particles, a very decided current will generally be seen to set into the branchial siphon, and a counter-current to proceed from the anal one; the water round the pedal opening being at the same time undisturbed.

The same arrangements are readily recognised in *Mya*. We lately had an opportunity of observing *Mya arenaria* in its native haunts, and watched the play of its siphonal currents under very favourable circumstances. This species, at the mouth of the Tyne, buries itself to a depth of 6 or 8 inches in a stiffish clay, mixed with shingle; and, in shallow pools left by the tide, the siphonal tubes may be seen just level with the surface of the muddy bottom in full action. The mud lies closely packed against the walls of the tubes, so that nothing is to be seen but the internal surface of the expanded lips of the siphonal orifices fringed with numerous tentacles. When it happens that the surface of the water is only a little above these orifices, a strong current can be distinctly seen to boil up from the anal siphon, and another, with a constant, steady flow, to set into the branchial one. These currents were quite visible to the naked eye without the aid of a glass, so long as the mollusk remained undisturbed. We watched one individual for nearly a quarter of an hour, and no interruption of them took place; and it was not until the siphon was touched that the tubes were withdrawn and the currents ceased to play. But the siphon soon made its appearance again at the surface, and the orifices once more expanding, the currents commenced to play as strongly as ever. On examining the animal thus in its natural position, it is impossible to doubt that the currents are connected. If not, whence comes the water that is constantly pouring out of the anal orifice? None can pass down externally to the pedal opening while the tubes are in action, for at this time they completely fill the channel they occupy, their walls being in close contact with the sides of the burrow; and the mud, though it lay loosely about and against the siphons, was not in the least disturbed, as it must have been had a current passed down outside the tubes. Yet to satisfy Mr. Clark's theory such a current must have existed.

On removing these animals from their concealed abodes, and placing them in a vessel of fresh sea-water, the two siphonal currents were generally found in action when the individuals were undisturbed. And further, on placing the shell with its back downwards and the pedal gape raised above the surface of the water, these currents still continued to play; the excurrent and incurrent being as distinctly observed as before.

With *Pholas* we tried another experiment, which would seem conclusive with regard to the connexion of the siphonal currents. A specimen of *Pholas crispata* was placed in a shallow vessel of sea-water, and, as usual, the currents soon commenced to play. The nosle of a blowpipe charged with sea-water stained with indigo was then placed at the inhalant orifice, and immediately a considerable quantity of the coloured medium was drawn into the animal. Watching carefully the result, we had soon the satisfaction of beholding a blue-stained stream issue from the exhalant orifice. This experiment succeeded three or four times, notwithstanding the caution of the animal, which generally, on receiving the contents of the blowpipe, immediately closed the inhalant orifice, and then gradually contracting itself, with a convulsive action, squirted out the coloured matter by the same orifice by which it was received. It is worthy of remark, that, if we did not succeed in the first attempt, the second was almost sure to fail; the internal apparatus being apparently then adjusted to prevent the passage of the coloured particles: and it is likewise remarkable that the coloured fluid exhaled was deprived of all the coarser particles.

These experiments may be deemed conclusive of the fact that the inhalant and exhalant currents are really connected. The mode of their connexion, however, remains up to this time undiscovered. For the purpose of explaining this difficult point, we have found it necessary to make a careful examination of the anatomical structure of these animals. The result is very satisfactory. We certainly find no opening between the foot and the gills, nor between the gills and the mantle. The branchial or ventral chamber is so far completely isolated from the anal or dorsal chamber; and without a careful observation of the currents in the living animal, as above alluded to, here the matter might have been allowed to rest.

But a simple experiment will at once solve this difficulty. Having killed a specimen of *Pholas crispata* with the siphonal tubes contracted as little as possible, and having placed it in diluted spirit a few hours to render the tissues firm without hardening them too much, we had again recourse to the blowpipe, charged as formerly with coloured fluid. The specimen on this occasion was opened down the ventral margin, exposing to view the whole of the gills stretched along the roof of the branchial cavity. The nosle of the blowpipe was passed into the anal siphon, and on removing the finger from the top of the pipe, the contained fluid immediately filled the anal chamber behind the gills, and then passing at once down the tubes between the laminæ of the gills, issued through ten thousand pores, and dyed the water in the branchial chamber. Thus in an instant the secret was explained;—the currents communicate through minute openings in the laminæ of the gill-plates.

Having thus satisfied ourselves of this fact, we next directed our attention to the structure of the gills. Accordingly the anal chamber was laid open, and its ventral wall was seen to exhibit four longitudinal rows of large orifices. These four rows of orifices, already well known to anatomists, correspond to the attached margins of the four gill-plates, which hang from the roof or dorsal membrane of the branchial chamber; this membrane being the ventral wall of the anal chamber,—the membrane, in fact, which divides the chambers.

These orifices lead into wide tubes which pass between the two laminæ forming each gill-plate. These interbranchial tubes lie contiguous and parallel to each other, and extend the full width of the gill, being bifid within its free margin. Thus it is evident that the tubes within the gill-plates communicate freely with the anal chamber. The laminæ forming the walls of these tubes were now examined through the microscope, when the whole was observed to present a regularly reticulated structure composed of blood-vessels; those passing transversely being the stronger and more prominent. The longitudinal vessels, rather far apart from each other, form the meshes into parallelograms. These meshes are open spaces, fringed internally with a narrow membrane and active vibratile cilia. The two vascular laminæ forming the gill-plate are really sieves to separate suspended molecules from the surrounding medium on the passage of the water from the branchial to the anal chamber;—an apparatus of the most exquisite beauty and perfect adaptation to the desired end.

We cannot understand how this beautiful structure escaped detection by the mercurial injection of Mr. Clark. Had the anal chamber been completely filled with mercury as supposed, we conceive that it must necessarily have found its way into the interbranchial tubes, and probably thence into the ventral cavity. Indeed we think that so large a quantity of mercury as was required to fill the anal cavity would have caused a rupture of the very delicate membrane dividing this chamber from the branchial one, even without the external pressure which Mr. Clark says he applied to it. The interbranchial tubes have been described by several anatomists, but they do not seem to have carried their examinations so far as to have ascertained the subserviency of these tubes to the branchial currents. They have in a few genera been described to be for the purpose of receiving the immature ova after leaving the ovary.

Having carried our inquiries so far, we were anxious to observe this exquisitely constructed apparatus in action, and accordingly laid open the branchial chamber of a living animal, by dividing the mantle along the ventral margin, and thus completely exposing to view the gills. The specimen was then placed in a shallow vessel containing sea-water, and in a short time the excurrent siphon was in full play, pouring out a constant, steady current. As the branchial siphon was laid open from end to end, its action was stopped; the branchial chamber, however, being submerged was always filled with water. We now slightly coloured the fluid with indigo and carefully watched the gills through a rather powerful lens, which revealed a sight of extraordinary interest. The gills lay stretched, two along each side of the body, their posterior extremities passing some way up the branchial siphon, and appearing like delicate waved fringes, with their surfaces transversely fluted; the flutes being caused by the distribution of the channels within the laminæ. The free margins, down upon which we looked, were rather thick and distinctly longitudinally grooved. Along this marginal groove a minute cord or stream of blue particles of indigo was observed moving towards the mouth, following accurately all the sinuosities of the much-undulated gills. Minute streams of similar particles were also observed coming up from the base on both sides of the gills to join the stream that continued its progress along the margin. These lateral streams passed for the most part up the furrows of the laminæ, and becoming incorporated with that on the margin, augmented its volume as it approached the anterior extremity of the gill. All these streams were sharply defined, and the particles of which they were composed did not move amongst themselves, but were formed into cords or threads rather than streams, apparently bound together by some tenacious fluid. These streams or cords continued to be formed and moved on for hours; the action being only occasionally retarded when the animal was disturbed, and the whole time the water was continually passing out of the excurrent orifice or anal siphon.

Thus considerable quantities of indigo were accumulated in the vicinity of the mouth and oral tentacles. These accumulations were composed of ravelled threads spun as it were by the branchial apparatus, from the scattered, nearly invisible particles of indigo in the surrounding medium.

On reviewing this curious spectacle the question naturally arises—how is the matter, divided into such minute particles, thus collected on the surface of the gills? Having arrived at a clear understanding of the structure of these organs, we can give a correct answer to this question.

We have seen that the two laminæ forming the walls of the gill are in fact in structure like sieves, and that the tubes which pass between them communicate with the anal chamber leading directly to the excurrent siphon. When the water is flowing out of this siphon, there is consequently a tendency to form a vacuum in the chamber and in all the tubes between the gill-laminæ. By this means, combined with the action of the cilia lining the meshes, the water introduced into the branchial chamber by the inhalant tube will be drawn through the meshes of the laminæ, and all the suspended particles of matter retained on the surface of the gill. The water being filtered, as it were, allows the particles to accumulate, and then by the aid of other cilia, they are formed into the defined streams above described. This is certainly one of the most beautifully adapted organic mechanisms that can be looked upon. As a breathing organ it is very complete; as a prehensile organ for securing food it is surely unrivalled for the minuteness and beauty of its structure.